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Perceptual Precedence in Picture Processing

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PERCEPTUAL PRECEDENCE IN PICTURE PROCESSING

by
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Perceptual Precedence in Picture Processing

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One important assumption of information processing models of human perception is that such processing occurs as a sequence of events or stages which take place over time. Recent investigations (Navon 1977, 1981) have suggested that the global aspects of a stimulus are perceived at an earlier stage in the time course of processing than are the local elements of the stimulus. Other studies (Kinchla & Wolfe 1979; Martin 1979; Hoffman 1980) have suggested that neither global forms nor local elements are necessarily perceived prior to the other structural level, but that other factors such as the size of the stimulus, the sparcity of the local elements, and the goodness of the form in the stimulus mediate the perceptual precedence of global and local levels.

Attempts to generalize the results of the above studies to real-world perception are very tentative. The nature of the stimuli used in global precedence research is markedly different from that of real-world stimuli.

Pomerantz (1981) has defined two types of relationships that exist between the global and local levels in visual stimuli: In one type there is no predictive relationship between the global and local levels (i.e., their identities are independent), while the second type contains mutually predictable (dependent) global and local levels. Real-world viewing involves the processing of stimuli of the latter type, but the global precedence studies to date have all utilized stimuli with independent global and local levels. It is not known whether generalizations can be made across these two configural types with respect to the perceptual precedence of the global or local levels.

The present study investigated perceptual precedence in pictorial stimuli in which the identity of global and local levels were dependent on one another. Perceptual precedence was measured through the use of a Stroop-like interference task, similar to that used by Navon (1977). The task required that subjects direct their attention to either the global or local level, as cued by the experimenter prior to each trial, and then respond "yes" or "no" to the presence of the cued object (local level) or scene (global level). Response latencies were recorded for each trial. Half of the trials contained inconsistent global and local levels, and the interference produced by the irrelevant level was taken as evidence for the processing precedence of that level. Stimulus display size was also varied across trials.

The results indicated that for small scenes, subtending 4° of visual angle, global precedence did occur, but for large scenes (16°) the opposite effect ("local precedence") was found. The pattern very closely parallels the findings of Kinchla and Wolfe (1979), using global-local independent stimul, suggesting that the relationship between the global and local levels is not critical in determining perceptual precedence.

A model was proposed in which the structural level first perceived is determined by the spatial frequency or size of the stimulus display. The model suggests that a critical sampling bandwidth exists and that the initial processing of a stimulus occurs at that level whose spatial frequency falls within the bandwidth. A post-hoc examination of the spatial frequencies present in the stimuli used in this study suggests that a band is centered at about 4 contour changes per degree of visual angle and ranges from 2 to 8 changes per degree.

This Thesis submitted by Steven W. Mann in partial fulfillment of the requirements for the Degree of Master of Arts from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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This Thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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Department Psychology

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Signature Steven W. Mann

Date July 15, 1982

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Finally, I dedicate this thesis to my father, Edward O'Brian Mann, whose life and example stand as a model

after which any man would do well to pattern his own life. I hope that I may do as well.

ABSTRACT

One important assumption of information processing models of human perception is that such processing occurs as a sequence of events or stages which take place over time. Recent investigations (Navon 1977, 1981) have suggested that the global aspects of a stimulus are perceived at an earlier stage in the time course of processing than are the local elements of the stimulus. Other studies (Kinchla & Wolfe 1979; Martin 1979; Hoffman 1980) have suggested that neither global forms nor local elements are necessarily perceived prior to the other structural level, but that other factors such as the size of the stimulus, the sparcity of the local elements, and the goodness of the form in the stimulus mediate the perceptual precedence of global and local levels.

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The present study investigated perceptual precedence in pictorial stimuli in which the identity of global and local levels were dependent on one another. Perceptual precedence was measured through the use of a Stroop-like interference task, similar to that used by Navon (1977). The task required that subjects direct their attention to either the global or local level, as cued by the experimenter prior to each trial, and then respond "yes" or "no" to the presence of the cued object (local level) or scene (global level). Response latencies were recorded for each trial. Half of the trials contained inconsistent global and local levels, and the interference produced by the irrelevant level was taken as evidence for the processing precedence of that level. Stimulus display size was also varied across trials.

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CHAPTER I

INTRODUCTION

Information processing models of human perception emphasize the view that perception is a process which occurs as a sequence of events taking place over time. Thus, if perception is examined at various points in its time course, a great deal could be learned about the individual steps through which perception occurs. This, of course, is one of the fundamental assumptions behind many research areas in cognitive psychology.

Although much of the research in cognitive psychology has been concerned with identifying and defining the various stages of perceptual processing, there is much current interest in the temporal sequence of processing. This interest has developed as evidence has accumulated which suggests that different aspects of a stimulus are processed at different rates. Navon (1977) reported a series of experiments which led him to posit that the processing of the global form in a stimulus was completed prior to completion of the processing of the local elements. The results of his experiments led Navon to postulate that global precedence operated in human perception, i.e., all perception proceeds from global analysis to a more local analysis.

Although subsequent research has suggested that the global precedence phenomenon is mediated by such factors as size (Kinchla & Wolfe 1979), sparcity of the local elements in the stimulus (Martin 1979), and others (see Hoffman 1980), the notion of global precedence has been widely accepted.

The generalization of the global precedence findings to more ecologically valid laboratory situations (e.g., picture processing) and particularly real world viewing is, however, very problematic. The stimuli employed by Navon, Kinchla and Wolfe, and Martin all involved alphabetic stimuli which are different from pictorial stimuli in a variety of very important dimensions (which will be discussed in detail later). The present research is intended to investigate the global precedence hypothesis with scenes rather than alphabetic stimuli, and thus address the issue of the time course of perception in picture processing.

The Time Course of Perceptual Processing

The early Gestaltists developed the basic assumption that perception is always of wholes, configurations, or forms (see Avant & Helson 1973). When making reference to this basic tenet of Gestalt thought, it is commonly stated that "the whole is more than the sum of its parts."

This statement, however, is somewhat inaccurate. Pomerantz and Kubovy (1981) state that neither Wertheimer, Koffka nor Kohler ever made such a statement, but rather asserted that the whole, or configuration, was different from the sum of the parts and, in addition, that perception of the whole occurred temporally prior to perception of the parts (p. 449; see Pratt 1969, pp. 9-10). This view is clearly very similar to the global precedence hypothesis presented by Navon (1977). Although Koffka, Kohler, and others of the Berlin school of Gestalt psychology were not specifically interested in the precise temporal sequence involved in perception, a lesser known group of Gestaltists, headed by Krueger of Leipzig, were interested in this very question. Sander, one of Krueger's co-workers, coined the term _Aktualgenese_ to refer to the presumed temporal sequence of events which occur during perception (see Flavell & Draguns 1957, for a detailed review). Werner later translated the term to microgenesis (Werner 1956).

Sander (1926, 1928) suggested that the sequence began with the perception of a diffuse undifferentiated whole. Figure and ground then become differentiated, followed by contour and inner content as the prior "skeletal Gestalt" was filled in through further elaboration of contour (Flavell & Draguns 1957; Unduetsch 1942). Support for the assertion that perception occurs from diffuse, undifferentiated wholes, which are later differentiated and sharpened, came from a variety of sources, such as early studies with Rorschach inkblots (Phillips & Framo 1954; Stein 1949), Rubin figure-ground cards (Wever 1927), and pictures (Cameron 1944; Dickinson 1926; Smith 1914). Despite the lack of precise control associated with some of these early studies, they do lend support to Sander's theoretical formulations and the global precedence notion.

Developmental Emphasis on Undifferentiated Perception

Several theories of development predict that perception develops with age, in the individual, in a fashion consistent with the global precedence hypothesis (e.g., Werner 1948; Solley 1966, Bower 1974; Piaget 1927). These developmentalists put forth theories which stress that the perception of children is "centered" (Piaget) or "undifferentiated" (Werner, Solley), and consequently adheres to the Gestalt rules of Primacy (wholes are prior to parts), Pragnanz (wholes tend to be complete, symmetrical, and simple), and Autonomy (wholes are governed by internal rather than external factors) (see Avant & Helson 1973). According to Piaget (1927), as the child matures, perception becomes increasingly decentered or differentiated, although it is unclear as to whether this decentering would affect the temporal precedence of wholes over parts in a single perceptual event. Piaget (and the other theorists) did not specifically address this issue, since they were not directly concerned with the temporal sequence in perception within the information processing framework introduced previously. The developmental studies of part-whole perception thus focus on age differences in abilities to perceive parts or wholes not on the temporal sequence of perception.

There is some experimental evidence to support the idea that children tend to perceive wholes at an earlier age than they do parts. For example, a study by Meili-Dworetzki (1956) utilized stimuli in which the parts and wholes had different meanings (e.g., a number of different fruits organized so that together they formed the figure of a man). She presented these ambiguous figures to children of various ages and to adults and found that the younger the child, the greater the probability that the child would see only the wholes. Thus, wholes were perceived at an earlier age than were parts. Meili-Dworetzki suggested that this finding may have resulted from an innate tendency to perceive wholes prior to parts.

A later study by Elkind, Koegler, and Go (1964), with nursery school to fourth grade students as subjects, also used ambiguous stimuli (constructed in the same manner as those of Meili-Dworetzki), and found that parts were perceived more easily than wholes by all age groups. These findings suggest that the results of Meili-Dworetzki were not due to an inborn perceptual tendency which favors wholes, and when combined with the Meili-Dworetzki study, can be interpreted as evidence that neither wholes nor parts are consistently perceived prior to the other. Elkind et al. state that differences in the results of these two studies probably stem from differences in the stimuli employed. Specifically, they suggest that configural properties of a stimulus, such as closure, good form, etc. determine whether wholes or parts are perceived when viewing any given stimulus.

Can Wholes Be Processed Prior to Processing of Component Parts?

Developmental theories present models of perception which assume that perception of wholes can occur without previous perception of the component parts of that whole. These theories have rarely questioned that assumption; consequently in the 1950s and 1960s little empirical evidence to either support or negate such an assumption was available. The major source of evidence in support of direct perception of wholes came from the Gestaltists' research which was largely based on subjective experiences.

As the information processing model, and specifically the notion of global-to-local processing, became increasingly useful in interpreting experimental results, and as a heuristic concept, the question of whether wholes can be perceived prior to identification of the component parts became critical. For example, can the word "LAMP" be perceived prior to identification of the individual letters L, A, M, and P which comprise the word? If the letters, or more generally, the low level features of a stimulus, must be identified, or processed, before the whole can be perceived, then global precedence is not possible. A processing sequence requiring processing of low level features in order to perceive a higher-level whole is precisely the reverse sequence, or local-to-global processing.

Intuitively, direct perception of wholes (i.e., perception of wholes without the necessity to first process low level features) is difficult to conceptualize. What is it that we perceive if it is not the lines and angles (features) that form individual letters or objects, which in turn combine to form the whole? Pomerantz (1981) suggests that various stimulus factors, such as proximity and similarity of the features, cause certain of the elements to group together. One result of grouping is the creation of emergent features which are recognized directly. Thus the wholes which are perceived directly are groups which emerge from the interaction of the features in the stimulus. The evidence in support of this grouping-emergent features concept will be reviewed below.

<u>Direct Perception of Emergent Features: A Review</u>. Sekuler and Abrams (1968) presented subjects with two dot patterns constructed by filling in various rows and columns in a four-by-four matrix. The task required that the subjects determine as quickly as possible whether the simultaneously presented patterns were the same or different. Separate groups of subjects received different instructions as to the criteria to be used in correctly identifying two patterns which were the "same." In one case "same" was the correct response if and only if the two patterns were

identical in every cell. A second group responded "same" if any single cell corresponded across the two matrices. Sekuler and Abrams reasoned that if the configuration is processed without processing each of the dots, then the former task (identical patterns) should result in shorter response latencies than the identification of a single matched cell. Response latencies were found to be longer in the single cell matching conditions thus suggesting that the configurations were processed prior to the individual dots.

A study by Pomerantz and Garner (1973) utilized a selective attention task to investigate perceptual grouping. They reasoned that when presented with stimuli comprised of two parts and told to classify the stimuli on the basis of only one of the parts, selective attention should be very difficult if the two parts are grouped and processed as a single unit. The classification task required that subjects perform a card-sorting procedure based on one of two elements on each card. When using stimulus cards containing paired parentheses (a similar set of paired brackets is shown in Fig. 1, Set A) the times required to sort 32 cards were longer than sorting times for a set of 32 from Set B (Fig. 1). This was interpreted as the failure of selected attention to perceive the parts individually for the stimuli in Set A. Pomerantz (1981) suggests that this failure of selective attention to a single element of a

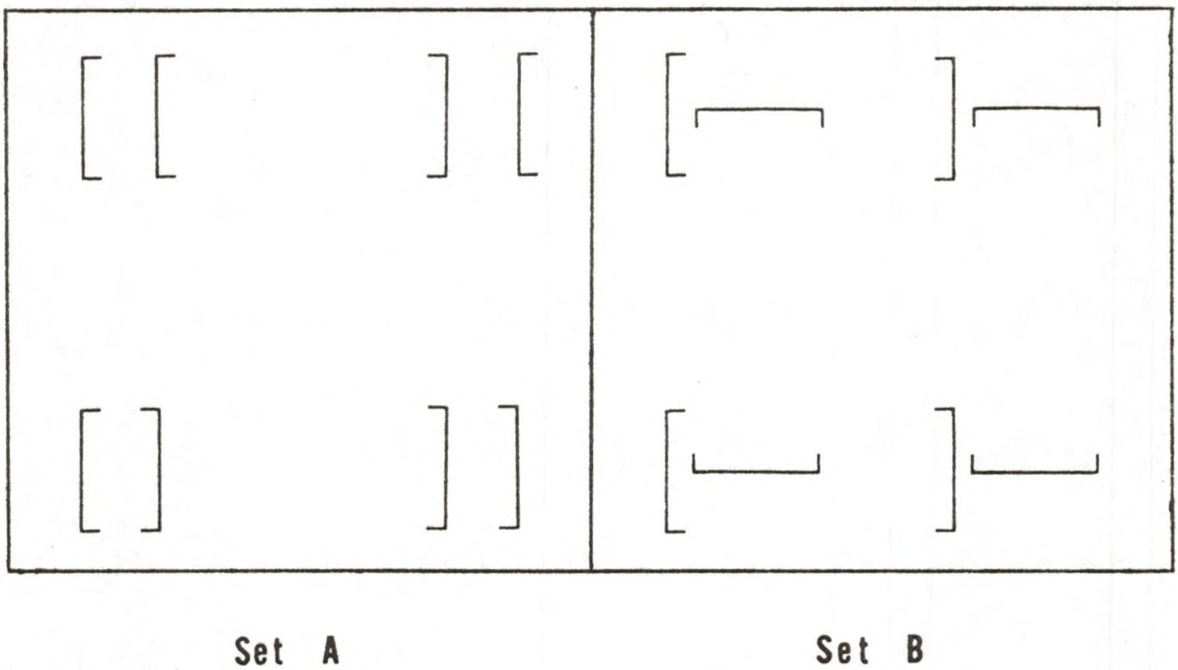

Figure 1. An example of perceptual grouping using bracket pairs. The bracket pairs in Set A are easily grouped, as demonstrated by a failure to selectively attend to single brackets within each pair, while the pairs in Set B are not easily grouped.

multielement display operationally defines perceptual grouping.

Since selective attention to single elements in perceptually grouped stimuli is difficult, it follows logically that divided attention, i.e., simultaneously attending to two or more elements in a multielement display, should be easy. Using the same two stimulus sets (Fig. 1), it could be predicted that classifying the stimuli in Set A in a divided attention task should require less time than the same task for Set B.

Pomerantz and Schwaitzberg (1975) asked subjects to classify stimuli similar to those in Set A such that the upper left and the lower right stimuli constituted one category of the two categories used in the task. The other category was comprised of the lower left and upper right stimuli. The task required that both elements in each pair be considered. As expected, where selective attention had been difficult with these stimuli (Pomerantz & Garner 1973), the divided attention task was very easy as reflected in faster sorting latencies. Gottwald and Garner (1975) have demonstrated a similar effect in a divided attention task using separable and integral dimensions, where attention was found to be more easily divided over integral (grouped) dimensions.

Direct processing of wholes has also been supported in a series of studies investigating the "word superiority effect" (Johnson & McClelland 1973, 1974; Massaro 1975; Reicher 1969; Wheeler 1970). These studies have demonstrated that letters are recognized more rapidly when embedded in words than when presented alone or in a string of unrelated letters. Schendel and Shaw (1976) performed a study to determine whether letters could be recognized more easily than individual features of the letters. For example, subjects were asked whether a briefly presented letter was an H or an N. Other subjects were shown a short line segment and asked if it was a horizontal or diagonal line (the critical line differentiating H from N). Recognition of the whole letters was found to be both more rapid and more accurate than recognition of the letter parts. This suggests that wholes (letters) can indeed be processed directly (without previous processing of parts).

Weisstein and Harris (1974) report results which suggest an "object-superiority effect," so named for its similarity to the word-superiority effect. Their results show that diagonal lines are processed more rapidly when presented within the context of cube-like shapes than when viewed in a flat two-dimensional array. Care was taken in constructing the cube stimuli so that the context provided no information which would differentially indicate any particular line orientation. While this finding supports that wholes, or in this case a contextual pattern, facilitated recognition of the diagonal line segments, the results were not conclusive. A third condition, in which the segment was presented alone (without context) produced the fastest responses. Thus, the object-superiority effect does not directly demonstrate that wholes are perceived before parts in all cases, but suggests that certain configurations do in fact result in more rapid processing than less meaningful patterns.

One study designed specifically to test for configural superiority effects was conducted by Pomerantz, Sager and Stoever (1977). They were interested in determining if a perceptual group (configuration) could be processed more rapidly than a single element of the group presented alone. The studies by Pomerantz and Garner (1973) and Pomerantz and Schwaitzberg (1975), which were previously discussed, showed that multielement stimuli were processed more rapidly when perceptual grouping occurred than were non-grouped multielement stimuli. The relevant comparison in the Pomerantz, Sager and Stoever study extends these studies by comparing processing times for perceptually grouped multielement stimuli (wholes) with those of single element displays (parts). The procedure used to investigate this question involved the use of stimuli organized into a 2 x 2 matrix. For the single element stimuli each cell of the matrix contained a simple geometric form, such as a curved line (parenthesis). Three of the four cells contained identical forms, while the fourth cell contained an odd element. Subjects were instructed to locate the odd element in the displays and their reaction times were recorded. Latencies from a second condition, in which the displays were constructed by adding a second parenthesis to each cell to form groups, were much shorter. The parenthesis added to each cell in the second condition was exactly the same, therefore it added no task-relevant information. The decrease in response latency in the grouped condition is taken as evidence that the grouped parentheses were processed as units without the processing of the single parenthesis which comprised the units, and that the units were processed more rapidly than parentheses presented in isolation.

This brief review has presented empirical evidence in support of the idea that perceptual wholes can be processed directly, i.e., without prior processing of the component parts which form the whole, and that, at least in some situations, the processing of the wholes is more rapid than the processing of the parts. There are, however, problems in attempting to generalize these findings. First, perceptual wholes can be found which result in longer response latencies than single elements. For example, Pomerantz, Sager, and Stoever (1977) constructed a third set of stimuli in addition to those mentioned above. This third set was also formed by adding a second parenthesis to each cell of the 2 x 2 stimulus matrix, however in this case the added parenthesis was one which did not group perceptually with the first. The orientation of the added parenthesis was rotated 90° from that of the original parenthesis (in each cell) and in this way grouping did not occur (e.g., see Fig. 1, Set B for a similar stimulus matrix). Response latencies in detecting an odd element in these displays were longer than latencies obtained with stimuli containing only a single parenthesis in each cell. Pomerantz (1981) refers to this as a configural inferiority effect.

Second, perceptual grouping can be disturbed by a variety of factors. In the Pomerantz and Schwaitzberg (1975) study, in which grouped stimuli were processed more rapidly than single element components, the grouping effect was found to lessen as the distance between the elements was increased. At large distances (2 to 8 degrees of visual angle) the components were processed more rapidly than the multielement displays, i.e., the perceptual grouping effect had disappeared.

Finally, and most importantly, the previous studies have shown that perceptual wholes are processed more rapidly than single elements in isolation. This, however, is not the question that is critical in determining whether, when shown a complex stimulus, the whole(s) is processed prior to the parts which are not embedded in a complex context. Having established that perceptual wholes can be processed directly, the important question of the temporal priority of wholes or parts can be addressed.

Global Forms and Local Elements In Conflict

In order to assess the perceptual precedence of global forms or local elements in perception some method was required to place the whole and the parts within a single stimulus display in such a way that they could be manipulated independently. Kinchla (1974) proposed that large configurations could be constructed from smaller ones, e.g., a large letter could be constructed by arranging small letters in the form of the large letter. Precedence could then be determined by comparing response latencies to both the global form and local elements following stimulus onset.

Pomerantz and Sager (1975) utilized this concept to construct stimulus displays in which the configuration and the identity of the local letters were varied. Effort was made to equate the discriminability of the global and local dimensions in the stimuli, since dimensions of greater discriminability are more difficult to ignore. The task was a classification task in which subjects attended to only one dimension and ignored the other. The comparison of interest was whether classification was more difficult when attempting to ignore either the global form or the local elements. The latency data showed that the global dimension was more easily ignored than the local dimension, even when stimuli with more discriminable global dimensions were used.

Similar stimuli were used by Navon (1977) to investigate this same question. Navon's stimuli were large letters formed out of small letters, equated on their global and local properties by selecting the global and local letters from a limited set of stimulus letters. By defining such a letter set, from which the global letter and local letters are selected, Navon suggests that identical features are available (across stimuli) at both the global and local levels. In his Experiment 3, the subject's attention was directed to a single level of the display via oral instructions, yielding two instruction conditions: global-directed and local-directed. Further, three types of stimulus displays were constructed to reflect three levels of global-local consistency. In one type, the large (global) letter and the small (local) letters were the same, e.g., a large S made up of small S's, and is termed a consistent stimulus. A conflicting display was one in which the identity of the small letters and the large letter were different. Neutral stimuli utilized a rectangle in place of letters as either the global or local stimulus or both.

The reasoning behind this experiment is similar to some of the studies previously discussed. Specifically, it was postulated that if subjects were unaware of the irrelevant level while processing the attended level, then no interference should result from that irrelevant level. If, however, the unattended level was completely processed prior to completion of processing of the attended level then interference could occur. In this situation presence of a conflicting stimulus would produce interference, while a consistent stimulus should not affect processing or perhaps facilitate it. The amount of interference produced, or lack thereof, would be reflected in response latencies.

Navon's results so strongly supported the temporal priority of global forms that he developed the global precedence hypothesis to explain those results. There are two findings which are particularly supportive of this hypothesis: first, response latencies to global forms were faster than local-directed latencies across all of the consistency conditions. The identity of the local elements was successfully ignored in the global-directed condition, suggesting that global processing is completed prior to completion of processing of the local features. Second, consistency of the displays produced a substantial effect on the speed of responses in the local-directed condition. Responding to the local element was much faster when the global form was consistent with the local element than when the global and local elements were conflicting. A logical interpretation of this result is that the global form is completely processed prior to the local elements of the display. In the global-directed condition, a response can be made based on the processing of the global form without requiring completion of the local processing. In the local-directed condition additional time is required to recognize the local features. If, upon subsequent completion of processing of the local letters, the two levels are in conflict, then further processing must occur to resolve this conflict. This extra processing time is reflected in the large latencies in the local-directed conflicting-stimulus situation. Based on these findings (and similar results from the other experiments reported in his 1977 paper) Navon concluded that global precedence operated in human perception.

Subsequent studies have suggested that the temporal sequence of perceptual processing is much less predetermined than the global precedence hypothesis predicts. Rather than an invariant global-to-local processing sequence, there appear to be a variety of factors which mediate global precedence. For example, Kinchla and Wolfe (1979) report results from a target detection task in which the stimuli were letters like those used by Navon. A target letter was presented auditorally before each trial followed by a 100 msec presentation of the stimulus display. The subject was to respond "yes" if the target letter occurred in either the global or local levels of the display or to respond "no" if the target was not present. In addition to varying the presence or absence of the target, occurrence of the target at local or global level, and the identity of the target letter, Kinchla and Wolfe also varied the visual angle subtended by the stimulus display. The height of the large letter subtended either 4.8°, 6.7°, 8.0°, 10.3°, or 22.1° of visual angle on any given trial. The global precedence hypothesis was confirmed for stimuli subtending 4.8°, 6,0°, and 8.0°, but reversed with the larger stimuli, thus favoring more rapid processing of the local elements over the global form.

The apparent conflict of these results with those of Navon can easily be reconciled by considering the size of the stimuli employed by Navon. As noted by Kinchla and Wolfe, none of the stimuli in Navon's experiments subtended more than 5.5° of visual angle, and therefore were of optimal size to favor global processing over lower level processing. Kinchla and Wolfe conclude their article by postulating that perceptual processing is neither exclusively global-to-local nor the reverse, but rather that a level with an optimal size or spatial frequency may be the first to be processed, regardless of the level of structure at which it occurs. They refer to this as "middle-out" processing, suggesting that after processing the features of some optimal size, subsequent processing occurs to both higher and lower level elements.

Navon (1981) counters the size argument by noting that size (visual angle) and retinal eccentricity are confounded for stimuli that subtend larger visual angles

(8° to 10° and above). Since the global aspects of large stimuli are processed predominantly in the periphery, he argues, it is logical that recognition should be more rapid for foveally processed local features. This issue is a complex one and will be treated in more detail in a later section; mention is made of it here simply to indicate that the results of the Kinchla and Wolfe study are not without disagreement.

Other mediating factors in the precedence of global forms have been found by Martin (1979) and Hoffman (1980). Martin demonstrated that the sparcity of the display, i.e., the number of local letters used to construct the global letter, also affects the order of processing. She reports that as sparcity increases (fewer local elements) the interference produced by the global letters on processing of local letters decreases. At higher levels of sparcity, the pattern of interference reverses such that local letters interfere with processing of the global letter. Thus sparcity, which can be manipulated independently of the visual angle (size) subtended by the stimulus display, also affects the temporal order of perceptual processing. Hoffman (1980) suggests, but does not present evidence for, a variety of factors which may influence the speed of processing the levels of a form. For example, he lists width ratio, number of elements, continuity of contours, and goodness of pattern all as possible mediating factors.

This section has presented evidence in favor of the global precedence hypothesis, which suggests that human perception proceeds from a global to local analysis of a stimulus. The evidence has been drawn from a series of studies which have utilized global and local elements together in a single stimulus display, constructed such that the same features exist at both the local and global levels. Subsequent studies have suggested that a global-to-local processing sequence is not invariant, but is mediated by other factors, such as the size of the display.

Relationships Between Global and Local Elements: Ecological Considerations

The choice of stimulus materials to be used in any experimental situation frequently involves a trade-off between experimental control and ecological validity; global precedence research certainly involves such a trade-off. Navon (1977, 1981) and Kinchla (1974) have developed and employed compound letters (stimuli consisting of a large letter made up of small letters) so that the global and local elements can be independently manipulated, i.e., such stimuli maximize experimental control. Consequently, the ecological validity of the stimuli (the similarity of the compound letters to real world viewing) is lessened. There are potentially critical differences between real world stimuli and the compound letter stimuli in terms of the relationships that exist between the global and local elements in those stimuli. These relationships will be the focus of the following section.

Configural Types. Pomerantz (1981) has delineated two types of configurations which are commonly constructed from local elements. In one type the configuration created by the local elements is the same regardless of the identity of the elements. The local elements in this type of configuration are simply placeholders; the identity of the global form is independent of the identity of the local elements. The configuration is a function only of the spatial arrangement of the local elements in this situation. An example of this configural type is presented in Fig. 2, Set A. The second configuration, shown in Fig. 2, Set B, adds the property of global-local dependence to the function from which the global configuration can be specified by the local elements. Here, a change in any one of the local elements alters the entire configuration. Pomerantz suggests that processing of the local elements in the first type of configuration provides no information about the configuration, thus there is no reason to process the local elements prior to the global one(s). It should not be surprising to obtain global precedence with such stimuli. However, in the second type of configuration, processing of the local elements provides a great deal of information about the global form; therefore neither local nor global precedence should be differentially favored by this type of configuration.

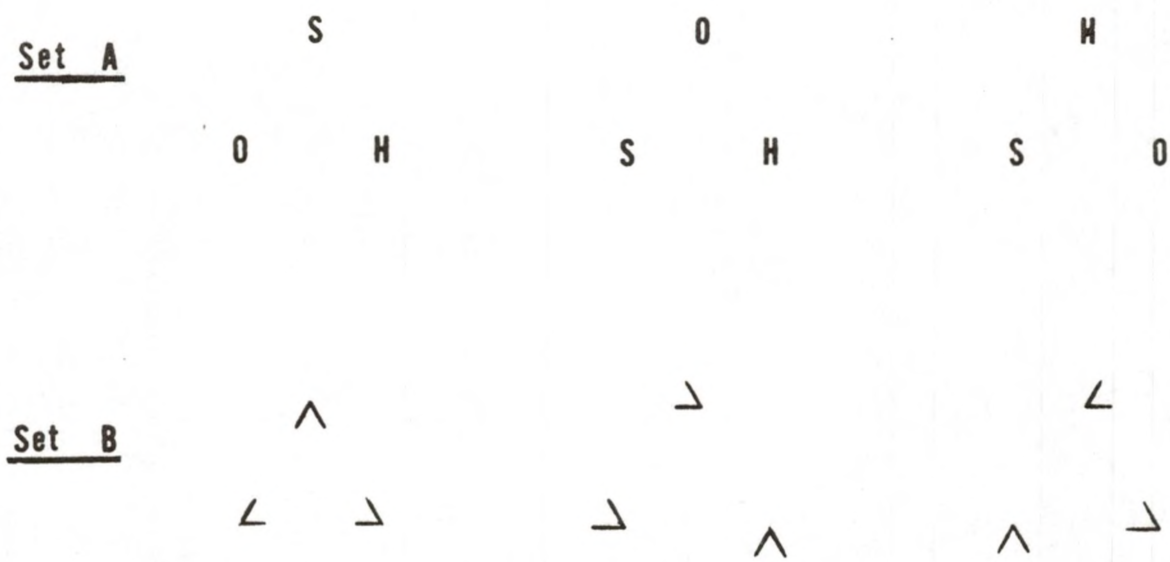

Figure 2. An example of global-local independent (Set A) and dependent (Set B) configurations. Rearranging the local elements in Set A has no effect on the triangular configuration, but rearranging the elements in Set B destroys the configuration.

The compound letters utilized by Navon (1977, 1981) and others (Kinchla & Wolfe 1979; Martin 1979; Hoffman 1980; Miller 1981) all correspond to the first type of configuration mentioned above. That is, when constructing the compound letters, the small letters serve as placeholders whose identity is totally independent of the large letter. The only constraint on the small letters is that they must be spatially organized into a pattern which defines the large letter. Real world viewing situations are not this type of configuration. When viewing a kitchen, for example, the identity of the local elements (objects) in the kitchen are certainly not independent of the global form (kitchen). Rather the majority, if not all, normal viewing situations correspond to the second of Pomerantz's configural types. Whether generalizations can be made from the global-local independent configurations (including compound letters) to global-local dependent configurations (including real world viewing) has not been demonstrated. In fact, Pomerantz (1981) suggests that the two may be unrelated (for reasons mentioned above, regarding the usefulness of local information in the two configurations). It seems clear that the global precedence hypothesis requires testing using stimuli with global-local dependent configurations which more closely approximate real world viewing. The present study involves such a test.

Rationale

The purpose of the present study was to investigate the relative temporal sequence of global and local processing in the initial phases of picture processing. Pictorial stimuli were selected in order to more closely approximate the real world viewing situation. The stimuli consisted of complex line drawings of scenes (global bases) which contained many objects, one of which (local object) was situated in the precise center of the scene. The local object was a commonly expected and predictable object in the global-local consistent condition and was replaced by an unexpected object in the global-local inconsistent condition. The stimulus set was designed so that the identity of the global and local elements were dependent upon one another, in contrast to the compound letter stimuli in which the global and local elements are independent. Further, this dependency is assumed to remain constant throughout the study despite the experimental manipulation which makes a consistent and inconsistent stimulus equally likely for any given trial. Since this interdependence of the global and local elements is a critical point in the rationale of this research, following is a statement of the stimulus properties which specify the relationship(s) which exists between the global form and local elements in a stimulus.

Formal Properties of Stimuli in Global Precedence Research. One important property of both the compound letter stimuli and complex pictorial stimuli relates to the spatial organization of the local elements. The elements of the display must be organized into a specific pattern in order for a meaningful global form to be present in the display. Thus, the local elements serve as placeholders in the overall configuration and the identity of the local elements is irrelevant. A global form and local elements can be differentiated solely on the basis of spatial organization simply by examining the relative size of the elements, i.e., in both the compound letters and in pictorial stimuli the global elements are larger than the local elements. The property of spatial organization is common across the two types of configurations previously discussed.

A second property of the stimulus material which must be considered is the configural or experiential dependence between the global and local levels. That is, based upon the observer's perceptual experiences, can the global level be predicted from the local elements or vice versa. This is the stimulus dimension which differentiates a global-local independent configuration from a dependent one. When the configuration is independent across the structural levels, then the only stimulus property inherent in the displays is spatial organization, and the relative sizes distinguish between the global and local levels. Since relative size is the only critical cue, then the local and global elements should be interchangeable, as they in fact are in the compound letter stimuli. However, when experiential dependence exists in the stimulus, then the dimensions which specify the global-local relationship are more stringent. The relative sizes of the levels still differentiate between them, but the levels are no longer interchangeable. Because of the dependence which exists, the identity of the elements becomes a second critical cue in the stimulus. The experience of the observer dictates that an element with a particular identity is always more global (or more local) than the element at the other level. For example, if one element is a stove and another element is a kitchen, the observer has no difficulty deciding which is the more local of the two.

In addition to these two properties, a third property can be determined. This property is the statistical or <u>experimental dependence</u> of the levels. In the real world this property is defined by experience and thus would be equal to (or be the same as) the experiential dependence. The need for some measure of experimental control requires that in laboratory studies, the statistical dependence be controlled. For this reason, it is typical for the identity of the local and global levels to be arbitrarily set such that the probability that a specific global or local element will occur on a particular trial is the same as the probability of the occurrence of any other possible element in the stimulus set. In other words, despite any experiential dependence which might exist in the real world, the experimental task arbitrarily requires that a statistical independence be maintained during the study. The implication of this experimental independence is different for the two configural types that have been discussed. When using global-local independent stimuli (compound letters) this simply requires that the same letters occur equally often at both the global and local letters (the stimulus set is identical for the two levels). Because of the experiential dependence which exists in global-local dependent configurations it is not possible to use the same stimulus set at each level. Rather, there is one set of possible global forms and another of local elements. Experimental independence is obtained by selecting each element equally often within a single level, but they can not be interchanged. For example, suppose that the set of global forms consists of a kitchen scene and a beach. The dependent set of local elements might consist of a toaster and a sand castle, respectively. Thus, there is an experiential dependence between the global and local levels, which means that a given element in one level uniquely predicts only one element at the other level (the toaster, at the local level, predicts the kitchen but not the beach). In order to maintain an experimental independence, the kitchen (and beach) must be presented equally often with both the toaster and the sand castle. Selecting the items in this way may result in stimuli with unexpected objects (a stove on a beach) and thus it may be argued that any experiential dependence in the stimuli will be destroyed. However, it seems more likely that in laboratory perception experiential dependence dominates experimental dependence. Considering the rarity of the laboratory situation, and that the laboratory is the only place where experimental and experiential dependence are not necessarily equal, the dominance of experiential dependence is very probable. That this should be so is essential if global-local dependent configurations are to be used to evaluate the global precedence hypothesis. The dominance of experiential dependence implies that if subjects are aware of the possible stimulus sets (one local, one global) and that one local (global) element has an experiential dependence with one and only one of the possible global (local) forms, then the level that completes processing first will automatically result in an expectation for the unique member of the other level to appear in the stimulus display, based on experiential dependence, regardless of the experimental independence which has been artifically imposed in the task. If this does occur, then a suitable test of the global precedence hypothesis can be made. The resulting test of global precedence with global-local dependent configurations would also be more ecologically valid than previous tests for the following reasons. It is proposed that real world viewing consists of the following properties: a unique pattern of global and local elements formed by a specific spatial organization, an experiential dependence between the global and local levels of the form, and third, an experimental dependence which is always equal to the experiential dependence (i.e., the experimental dependence is controlled by the natural occurrence of global and local forms in the environment). A task is more ecologically valid to the degree to which it approximates these properties as they exist in real world viewing. The third property above (equal experimental and experiential dependencies) is not met in laboratory settings where the experimental dependence is strictly controlled. Therefore, laboratory tasks are more ecologically valid to the degree to which they meet the remaining two properties. However, the compound letter task satisfies only the property of spatial organization, while both the spatial organization and experiential dependence properties can be met by employing stimuli in which the global and local elements are dependent on each other. For this reason, the present study has utilized the pictorial stimuli previously discussed. Thus, the set of global forms used maintains an experiential dependence with the set of local elements, i.e., each form predicts one and only one element.

Evaluation of the global precedence hypothesis with experientially dependent stimuli was accomplished in the present study through the presentation of complex line drawings containing a global form and a local element placed in the center of the scene, to subjects whose attention had been directed to either the local or global level of the stimulus prior to viewing the scene. Their attention was directed by means of a cue presented orally prior to onset of the stimulus. The cue consisted of a single question of the form "Is this the (name of local or global element)?" Following presentation of the cue, the stimulus was displayed. The subjects responded "yes" or "no" to the cue question by pressing one of two keys placed in front of them. The response also terminated the stimulus exposure. Response latencies were recorded for each of the trials. As previously outlined, the consistency or inconsistency of the global and local levels was randomly varied on each trial. The size (visual angle) of the display was also varied. The display sizes used were 4.0, 8.0 and 16.0 degrees of visual angle. These sizes were selected in order to determine if the mediation of global precedence by size, as reported by Kinchla and Wolfe (1979), would be obtained with experientially dependent pictorial stimuli.

It was hypothesized that the interference produced by inconsistent displays would vary with the size of the display and whether the subject was directed to attend to the global or local level of the stimulus. Specifically, for the small size scenes the local level should produce no effect on the global levels, but an inconsistent global level should cause longer response latencies than would be produced by a consistent global level when attention is directed to the local level. These predictions are consistent with the global precedence hypothesis of Navon (1977). The large size scenes were hypothesized to result in the opposite effect, i.e., "local precedence," which would result in no effect of global forms on local attention, but longer latencies to global forms when an inconsistent local element is present in the display than when the local element is consistent with the global form. These hypothesized effects of size are based on the findings of Kinchla and Wolfe (1979). The medium size scenes were expected to show an effect intermediate to that of the large and small scenes.

CHAPTER II

METHOD

Design

Three factors were varied in the study. First, the subjects' attention was directed to either the global form or to the local elements in the stimulus display via a verbal cue question asked prior to stimulus onset. The size of the stimulus display and the consistency (or inconsistency) of the global form and local elements were characteristics of the stimulus itself which were varied on each trial. Thus there were 2 (directed-attention) x 3 (size) x 2 (consistency) conditions which were varied within subjects.

Also controlled were the correct answer and identity of the cued scene or object. The task required that the subject answer the cue question by responding "yes" or "no," depending on the presence or absence of the cued global scene or local object. The correct answer was counterbalanced across trials, as was the identity of the specific scene or object which was cued.

In order to control for stimulus-specific effects an independent replication of the study was performed using a different stimulus set.

Subjects

Forty undergraduate students (28 female) at the University of North Dakota served as subjects. All of the students reported normal or corrected-to-normal vision. Each subject participated in one experimental session, approximately 30 to 45 minutes in duration, as partial fulfillment of course requirements of an introductory course in psychology.

Stimuli

Two sets of pictures, each set consisting of two line-drawing scenes, were selected to serve as the global forms. The scenes were originally drawn for use in previous research in picture perception (Penland 1979). These scenes were selected such that each scene contained several objects, one of which was located in the center of the scene and was highly predictive, or diagnostic, of the theme of the scene. The predictiveness of the center object had been empirically determined in previous research (Antes, Mann, & Penland 1982) by raters who indicated that the object was very likely to appear in the scene (or similar scenes) and unlikely to appear in other types of scenes. Each picture set thus contained two global forms (scenes) and two local elements (center objects). In addition, the scenes and objects in each picture set were grouped so that the two scenes within a set would meet the property of experiential dependence, that is, each element (or form) at one level uniquely predicted one and only one form (element) from the other level.

The two global scenes and their respective predictable local objects formed the consistent stimulus displays. The inconsistent displays were formed by exchanging the objects from the two scenes. The local objects were equated in terms of their absolute size within the global scenes. Thus, each picture set contained four line-drawings: two consistent scenes and two inconsistent scenes. The four scenes from the first picture set are presented in Fig. 3. The second picture set was constructed so that an independent replication of the study could be performed with different scenes. The scenes used in the replication are shown in Fig. 4. The four scenes from each picture set were photographed and slides made in three different sizes for each scene. The size ratio of the slides was 1:2:4, which allowed the slides to be used to produce projected images subtending 4°, 8°, and 16° of visual angle, respectively.

Procedure

Upon arrival, subjects were informed about the nature of the task and were familiarized with the four scenes at each of the three sizes (12 slides total; two consistent and two inconsistent scenes for each of the three sizes). The instructions indicated that each trial would be preceded by a cue question which would inform them of the

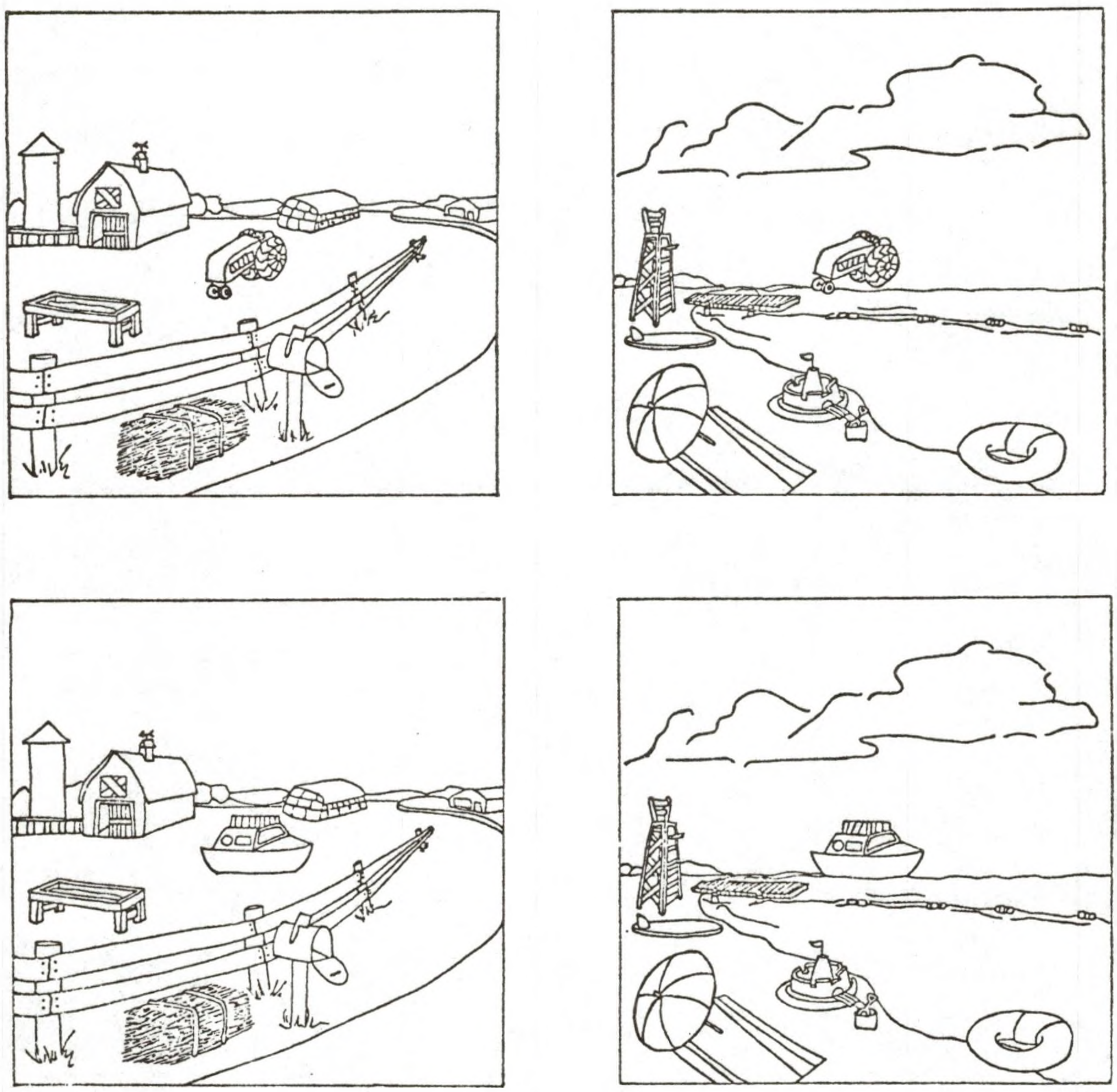

Figure 3. Picture stimuli used in Replication # 1.

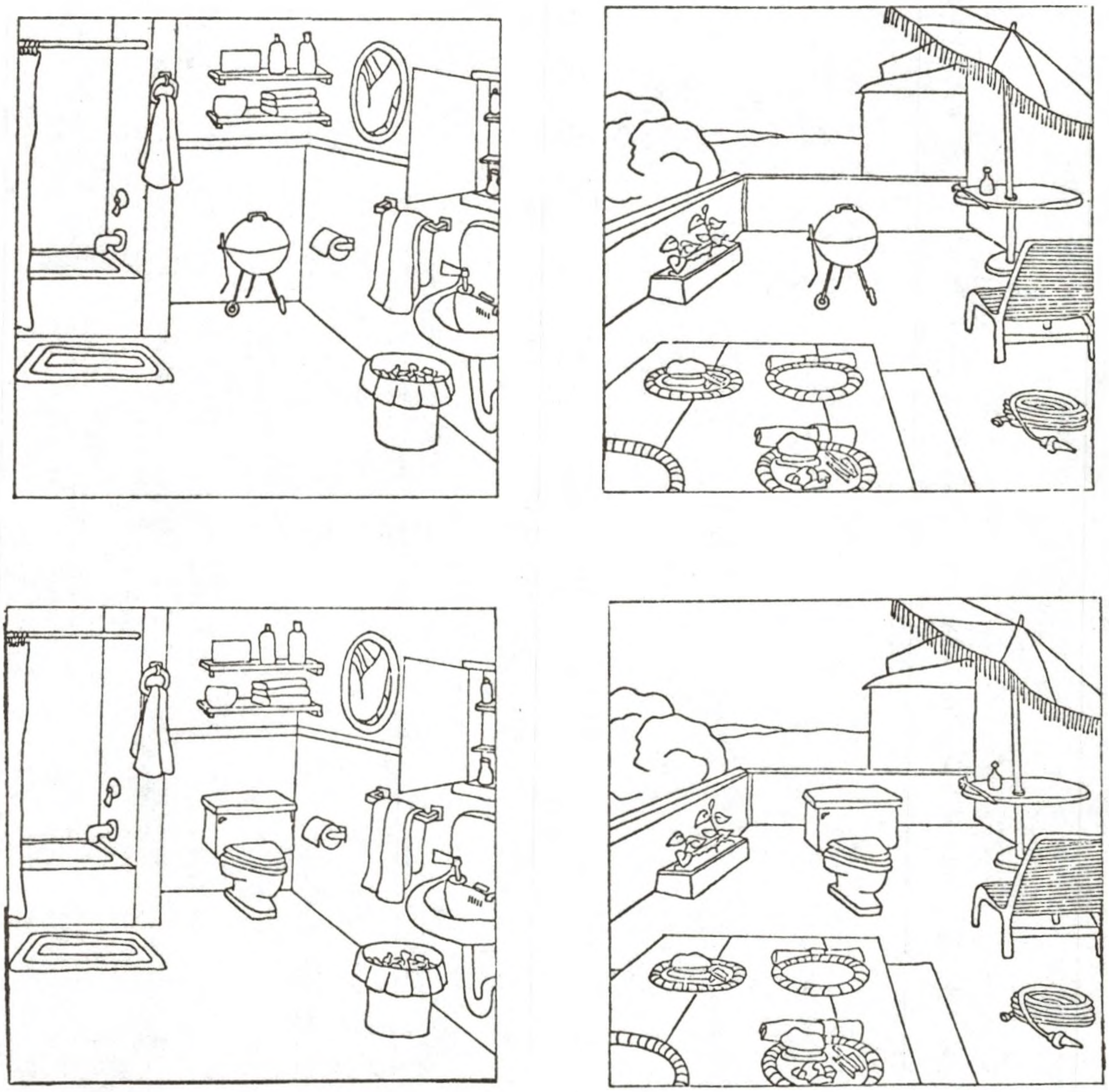

Figure 4. Picture stimuli used in Replication # 2.

object or scene (global or local level) on which to base their response on that trial. The task required a simple yes or no response, the correct answer indicating whether the cued object or scene was present in the stimulus.

The cue question served to direct the subject's attention to either the global scene or local object. This directed-attention factor (global-local) was blocked within subjects and counterbalanced across subjects. Each block consisted of 72 trials, and was preceded by 10 practice trials all of which directed attention to the appropriate level for the block which followed. Within each block, the size of the display (4°, 8°, or 16°) and the consistency (consistent or inconsistent) of the display were randomly varied. In addition, two other factors, not of interest in the design, were controlled to minimize their possible effects. First, the correct answer (yes or no) was varied such that the probability of a yes (no) answer was .5 on any given trial. The same control was placed over the identity of both the local and global elements selected on any trial. The entire randomization process was performed independently for each subject by a PDP 11/34 minicomputer. The following constraints were placed over the randomization: (a) no single level of the size, consistency, correct answer, or scene could occur more than four times in succession; and (b) each combination of those factors must occur equally often within each block.

Thus each subject received a different random order of experimental trials. The order of presentation of practice trials was fixed.

Since the local object was always located in the center of the scene, it was essential that the subject be fixating the center point at the moment of stimulus onset, so that any possible effect of the local element could exert its influence on perceptual processing. Thus, subjects were informed that it was critical that they fixate a center 'X' placed on the screen so as to correspond to the center of the projected scenes. On each trial, prior to stimulus onset and following the cue question, subjects were also cued to fixate the center X.

Stimulus onset on each trial was initiated by the experimenter following verbal presentation of the cue question and the fixation cue. Stimulus initiation also started a reaction time clock. The slides were presented by a Kodak carousel projector, upon which a Lafayette tachistoscope shutter was mounted, onto a rear projection screen located at eye-level at a distance of 52 in. in front of the subject. The subjects responded by pressing one of two telegraph keys mounted on the table within comfortable reach. Each key was clearly labeled "yes" or "no." The instructions given to the subjects indicated that they were to respond as quickly as possible while maintaining as much accuracy as possible. The keypress response terminated the stimulus exposure and stopped the reaction time clock. The latency and the subject's answer (Y/N) were then entered into the computer by the experimenter. A short break was taken following the first block.

Twenty subjects served in each of the two replications. The procedure was exactly duplicated in the second replication, the only difference being the picture set used.

CHAPTER III

RESULTS

Two dependent measures were recorded for each experimental trial: response latency and the subject's answer (yes or no). It is common practice, in studies using reaction time as a dependent measure, to analyze the latencies only for the trials which the subjects answered correctly. However, for this to be justifiable, the percentage of errors in the data must be low. The first analysis, then, concerns the error data.

Error Data

The overall error rate was 5.97% (344 errors out of 5760 total trials). The distribution of the errors across the experimental conditions is shown in Table 1. The number of errors in each condition were analyzed using an analysis of variance (ANOVA). The factors in the ANOVA were Directed-Attention (global-local), Consistency (consistent-inconsistent), and Size (large, medium, small), yielding a 2x2x3 within-subjects ANOVA. The analysis produced only one significant factor: Consistency, $F(1,38)=4.724$, $p < .05$. Inconsistent displays were found to result in more errors (3.52%) than consistent displays (2.44%).

Table 1

Number of Error Trials per Condition

Consistency	Directed-Attention Global	Local
Large Size		
Consistent	19	21
Inconsistent	43	31
Medium Size		
Consistent	17	22
Inconsistent	33	26
Small Size		
Consistent	30	32
Inconsistent	36	34

Note. Total trials per condition = 40 subjects x 12 trials = 480 trials.

Because of the relatively low error rate, latencies on the error trials were not included in subsequent analyses.

Latency Data

The results from the two replications were analyzed with separate ANOVAs and together with Replication as a factor. The separate ANOVAs produced identical results and the combined analysis resulted in no interactions involving Replication. The lack of differences in the replications suggests that the effects to be reported are not picture specific, as different picture-sets were used in each replication. Consequently, the latencies from both replications are reported together.

Median correct latencies were computed for each subject across the 12 trials for each of the 12 conditions. Table 2 presents the mean of these median latencies over the 40 subjects. The results are presented graphically in Figure 5. The data suggest that for the large scenes global precedence did not occur. Instead the pattern indicates local precedence, i.e., the global level had no effect on latency when the subject was locally directed, but when globally-directed, interference occurred from the local level of inconsistent displays and resulted in longer response latencies on those trials, as shown in Fig. 5. This pattern is the reverse of the pattern found by Navon (1977) in his studies, but corresponds to the

Table 2

Mean of the Median Correct Trial Latencies
for each Condition

Consistency	Directed-Attention Global		Local
Large Size			
Consistent	690	>	649
	^^		''
Inconsistent	773	>>	655
Medium Size			
Consistent	680	=	663
	^^		^^
Inconsistent	736	>	707
Small Size			
Consistent	764	=	752
	^		^^
Inconsistent	798	=	813

Note. All times in msec.

Note. = non-significant pairwise comparison

> significant pairwise comparison p < .05

>> significant pairwise comparison p < .01

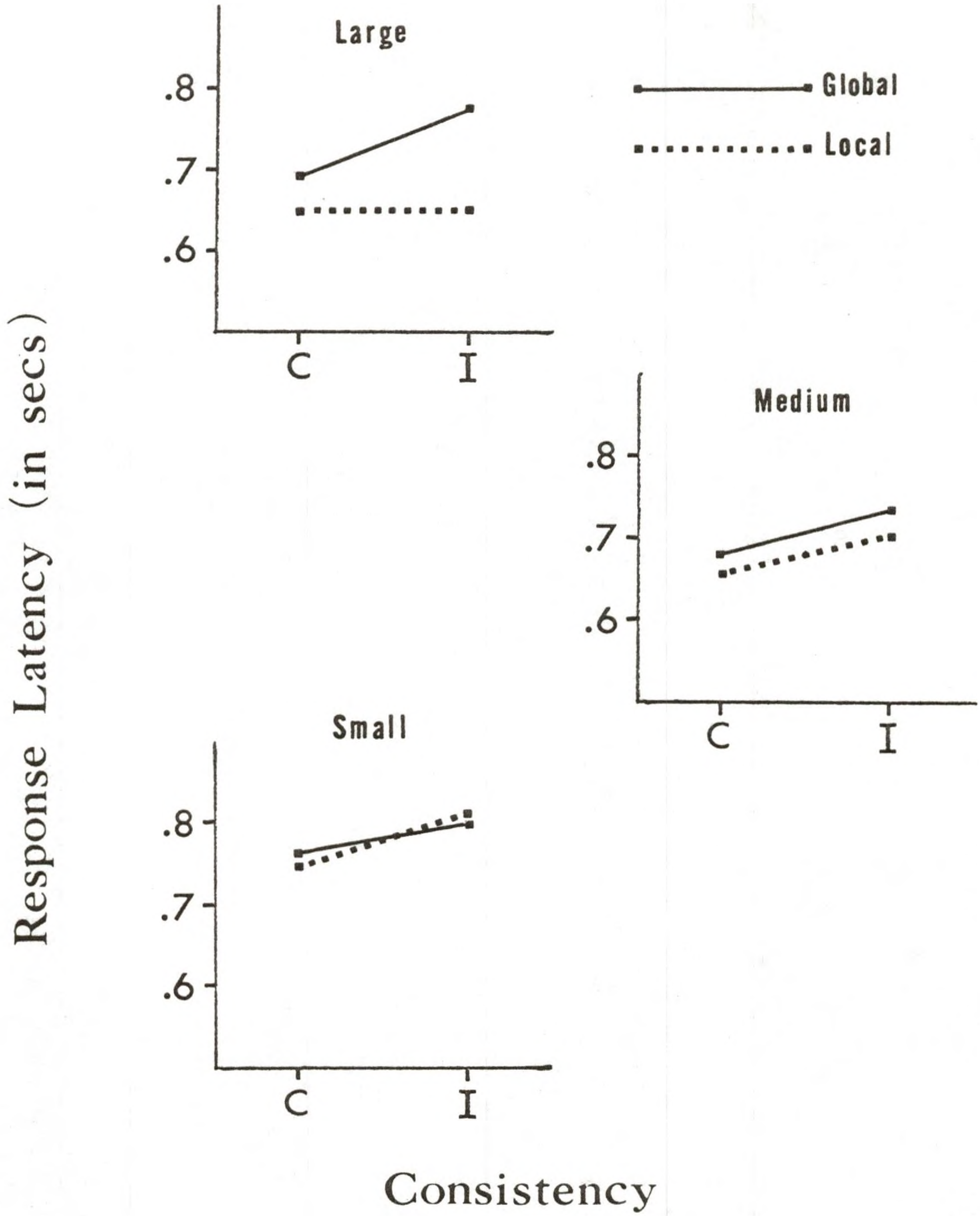

Figure 5. Response latency as a function of Directed-Attention (global and local) and Consistency (C = consistent, I = inconsistent) at each Size.

local precedence found by Kinchla and Wolfe (1979) and the hypothesis outlined in the introduction.

The small scenes did demonstrate a global precedence effect. Inconsistent displays affected both globally- and locally-directed trials, but the interference was greater for the locally-directed trials. Response latencies increased by 34 msec from consistent to inconsistent displays for the globally-directed trials, but the increase was 61 msec for the locally-directed trials. Thus, the global forms in the inconsistent displays produced greater interference to local processing than occurred with local objects on globally-directed trials.

These precedence patterns, found in the large and small scenes, were absent from the medium size scenes. In these scenes, the consistency of the display affected both local and gobal processing nearly equally (see Fig. 5), although the effect was slightly greater for globally-directed trials.

To test these effects, the median correct latencies were entered into a 2 (Replication) x 2 (Directed-Attention) x 3 (Size) x 2 (Consistency) x 20 (Subjects within Replication) mixed factor ANOVA, with Replication as the only between-subjects factor. The Replication factor showed no significant main effect and did not interact with any of the other factors (all p's > .5; the ANOVA summary table is reproduced in Table 3). As previously

Table 3

Replication by Directed-Attention by Size by Consistency ANOVA Summary

Median Correct-Trial Latencies

Source	df	Mean Squares	F
Replications (R)	1	0.032	0.152
Subjects within Replications (N/R)	38	0.209	---
Directed-Attention (A)	1	0.135	5.585*
R X A	1	0.000	0.002
A X N/R	38	0.024	---
Size (S)	2	0.412	97.830***
R X S	2	0.007	1.728
S X N/R	76	0.004	---
Consistency (C)	1	0.268	72.196***
R X C	1	0.003	0.817
C X N/R	38	0.004	---
A X S	2	0.068	21.458***
R X A X S	2	0.000	0.149
A X S X N/R	76	0.003	---
A X C	1	0.013	3.404
R X A X C	1	0.001	0.340
A X C X N/R	38	0.004	---

Table 3--Continued

Source	df	Mean Squares	F
S X C	2	0.000	0.067
R X S X C	2	0.001	0.261
S X C X N/R	76	0.004	---
A X S X C	2	0.027	9.209***
R X A X S X C	2	0.001	0.204
A X S X C X N/R	76	0.003	---
TOTAL	479	0.024	

* $p < .05$
*** $p < .001$

stated, the absence of replication effects suggests that the results are not picture specific.

The main finding of interest is the significant three-way interaction between the Directed-Attention, Size, and Consistency factors, $F(2,76) = 9.209$, $p < .001$. Post-hoc Neuman-Keuls analyses (see Table 2) showed that the latencies to consistent and inconsistent displays, at the large size, were significantly different ($p < .01$) for the globally-directed trials, but not for the locally-directed trials. The pairwise comparisons between consistent and inconsistent displays at the medium size were significant for both the globally- and locally-directed trials, the inconsistent displays yielding longer latencies in both cases (see Table 2). The same is true for the small size, although the magnitude of the differences is larger for the locally-directed trials.

The finding in the three-way interaction that global precedence is mediated by size is also supported by the significant Directed-Attention x Size interaction, $F(2,76) = 21.458$, $p < .001$. The pattern of results with this interaction parallels the three-way interaction in that for the large-size scenes, locally-directed trials produce shorter latencies than the globally-directed trials. This difference is lessened, although still present, for the medium size, and begins to reverse for the small scenes. Thus, as the size of the display increased, the relative time required for a subject to respond to a global form also increased.

The two significant interactions discussed above are the findings most relevant to the present study, however there were also significant main effects of all three factors. The Directed-Attention main effect, $F(1,38) = 5.585$, $p < .05$ reflected a general trend toward shorter latencies for the locally-directed trials. The Consistency of the display was also significant, $F(1,38) = 72.196$, $p < .001$. This main effect supports the predictable result that inconsistent displays result in longer response latencies than do consistent displays. Finally, the Size factor was also significant, $F(2,76) = 97.83$, $p < .001$. Post-hoc comparisons showed no difference between the large and medium sizes, but both produced shorter latencies than latencies to the small size scenes.

It is frequently the case that latency data are highly variable, and that heterogeneous variances in treatment conditions can cause problems in interpreting ANOVA results. The standard practice in such cases is to perform a log transformation on the data and enter the resulting log scores into an ANOVA. Such a transform was made on the median correct-trial latencies and an identical 2x2x3x2x20 ANOVA performed for the log scores. The results of the log transform ANOVA, presented in Appendix A, did not differ in the significance of a single factor from the analysis of the median correct-trial latencies; consequently only the untransformed analysis is reported.

CHAPTER IV

DISCUSSION

One important emphasis of this study was to examine the global precedence phenomenon with stimuli in which an experiential dependence existed. The compound letter stimuli, used in many previous studies, are formed of global and local levels which are experientially independent, while pictorial stimuli do not have this independence. Pomerantz (1981) has suggested that this relationship between the global and local levels differentiates two types of configurations and that experimental results obtained using one configural type may not be generalizable to the other type.

The present study found that, for experiential dependent pictorial stimuli, global precedence is mediated by the size of the stimulus display. The predictability, or consistency, of the global and local levels within a stimulus display was found to be less important for large scenes when the attention of the subject was locally-directed than when globally-directed, suggesting that the local element in the display was completely processed prior to completion of the processing of the global form. Consequently, an inconsistent global form produced no interference on the processing of the local element on the locally-directed trials. The opposite pattern was found for the small scenes (i.e., global forms are processed more rapidly and are unaffected by local elements when the observers attention is globally-directed). In addition, this mediating effect of size on perceptual precedence holds even when the consistency of the display is not considered. The two-way interaction of Size and Directed-Attention also shows that for larger scenes, locally-directed trials resulted in shorter latencies than globally-directed trials. The globally-directed trials produced shorter latencies than the locally-directed trials for the small size. The results replicate the results of Kinchla and Wolfe obtained with experientially independent stimuli.

Thus, independent tests of global precedence using stimuli with experientially independent (compound letters--Kinchla & Wolfe 1979) and dependent (pictorial stimuli-the present study) global forms and local elements have produced identical results. It appears that Pomerantz's two configural types (and by implication the experiential dependence which differentiates the types) do not differ in terms of the relative priority (or precedence) of global and local levels in perceptual processing.

The extension of Kinchla and Wolfe's results with compound letters to real-world stimuli, and the finding that experiential dependence is not critical in differentiating the two, suggests the need to identify common characteristics between Kinchla and Wolfe's stimuli and the real-world pictorial stimuli which might have led to the comparability of the results from studies using these different stimuli.

In the previous discussion of the properties of stimulus materials, it was stated that one common property of compound letters and pictorial stimuli is that a unique spatial organization, or pattern, must exist in the local elements in order for the global form to emerge. Within this pattern the identity of the elements is not important; that is, the local elements serve only as placeholders. However, and this point was also introduced previously, the global form and local elements in the spatial organization can be specified simply by reference to their relative sizes: the global form is always larger than a local element. This relative size relationship holds for both compound letters and picture stimuli, and probably for nearly all normal viewing situations. The importance of the absolute size of a stimulus has already been demonstrated (Kinchla & Wolfe 1979, and the present results) and it appears that absolute size and relative size may combine to determine the level of the stimulus which will first complete processing.

In order to determine the contributions of absolute and relative size, the information given by each of these size characteristics must be considered. In the previous paragraph it was suggested that relative size distinguishes local elements from global forms, the former being smaller than the latter. However, this same information can be obtained from knowledge of the absolute sizes of the two levels. That is, if the absolute sizes of a global form and its local elements are known, then the relative size of the two levels is also specified. Thus, the information available from relative size appears to be redundant, in that the relative size is already known from the absolute sizes of the two levels. The fact that relative size is important (which is suggested by the common spatial organization in the stimuli) may be reemphasizing the importance of absolute size, since relative size provides only information already available from knowledge of the absolute sizes. In other words, both the experimental manipulation of size and the common stimulus property of spatial organization in compound letters and pictorial stimuli point to absolute size as a critical variable in perceptual precedence.

Kinchla and Wolfe (1979) proposed a model of perceptual precedence based upon absolute size, or spatial frequency. The introduction of spatial frequency in their model is necessary because size and spatial frequency are often confounded in visual stimuli. The notion that spatial frequency (and consequently size) may be important in perception has been receiving increased attention in the past few years (e.g., Broadbent 1977; Graham 1981; Kinchla & Wolfe 1979). Spatial frequency, as applied to visual stimuli, represents the number of cycles of light-dark changes per unit distance in the stimulus (Graham 1981), the usual unit of distance being a degree of visual angle. For example, a stimulus picture with a large number of small objects would have more lines (dark to light changes) over the stimulus and hence a higher spatial frequency than a picture with fewer objects and more open areas. Using this example, it is simple to understand how increasing the size of a display decreases the number of lines, or changes, over a constant unit distance in the stimulus. In other words, an increase in size decreases the spatial frequency. For this reason, size and spatial frequency are usually confounded in any size manipulation. Interestingly, Martin's (1979) study on sparcity of a display as a mediator in global precedence can also be interpreted in terms of spatial frequency; when fewer elements comprise a global form within a constant area, then spatial frequency is also reduced by this change.

The hypothesis proposed by Kinchla and Wolfe, and supported by this study, suggests that there exists a critical sampling bandwidth (range of sizes or spatial frequencies) from which the initially processed level of a form is selected. Subsequent processing can occur to other levels in the stimulus which are either higher or lower (more global or local) levels within the stimulus. For example, in the present study, the farm (global scene) would fall within the sampling bandwidth for the small scenes (4°) and so the farm is completely processed prior to completion of processing of lower (more local) levels, such as the tractor. When the large scenes are shown the farm is much larger and thus is no longer within the sampling window or bandwidth. Now, a more local object (the tractor) is of the proper size (or spatial frequency) to be the first structural level to complete processing. After the processing of the level(s) within the bandwidth, processing occurs to other levels; for the large scenes, later processing would occur to the more global levels and possibly also to the more local features which comprise the tractor (e.g., the tires, steering wheel, the seat). Kinchla and Wolfe (1979) have termed this processing sequence "middle-out processing."

Retinal Location of Structural Levels

Although the size or spatial frequency model is apparently capable of explaining a variety of the results obtained in perceptual precedence research, it is not without criticism. Navon (1981) argued that in stimuli that subtend more than 2° or 3° of visual angle, retinal eccentricity is confounded with globality, i.e., the global form of the stimulus is seen predominantly in the periphery while the local element(s) is seen foveally. Thus, the local element is favored over a global form by means of its foveal processing rather than because of local precedence. While it is true that with larger stimuli the majority of the global form is extrafoveal, it is not clear that this favors processing of the local form. In fact, Navon (1977) states in his section on the functional importance of global precedence that an initial processing phase which extracts information from low resolution areas of the visual field would be very valuable to guide subsequent processing. Such an extraction phase would favor global forms as the first level to complete processing.

There are a variety of studies which suggest that such an extraction phase does occur with peripheral information. Williams (1966) demonstrated that a cue to the color or size of a stimulus could be effectively used to locate a peripherally viewed visual target. Antes (1981) also found that color could be used as a cue to guide visual search when a target was presented up to 9° into the periphery. Semantic information could be utilized by subjects in the search task only for targets viewed up to 3° into the periphery. Not only can information be extracted from peripheral areas in the absence of foveal stimuli, but Goolkasian (1981) has shown that when competing stimuli are presented in the fovea and parafovea, subjects were able to ignore a foveal distractor while processing a parafoveal target viewed at either 7° or 15°

into the periphery. This pattern did not hold for targets placed 25° away from the fovea. Thus, it appears that in tasks requiring processing of information across retinal locations, foveal information does not always dominate. Goolkasian suggests that visual processing capacity can be flexibly allocated across retinal locations in response to possible attentional demands or expected sources of relevant information.

Breitmeyer & Ganz (1976) discuss implications of the two visual systems, the ambient and focal systems, which also support the concept of an initial extrafoveal extraction phase. The ambient system (or transient vision) operates principally in the periphery and is characterized by a rapid decay rate, very rapid transmission, and is sensitive to low spatial frequencies (or global forms). This system is connected directly to the superior colliculus, which accounts for its high rate of transmission. The second system is the focal system, or sustained vision, and is tied to the foveal visual field. This system, in contrast to the transient system, maintains a sustained signal, which is transmitted more slowly and is sensitive to high spatial frequencies; detailed local information. This model suggests that peripheral information may be processed by the transient system before the sustained system can complete processing of the foveal information.

It seems clear then, that Navon's (1981) argument that local elements are favored by means of their foveal presentation does not necessarily hold. Further, although globality and retinal eccentricity may be confounded, this may be part and parcel of being global. In real world viewing situations it is certainly likely that most of the global information will be viewed extrafoveally (but, see Navon 1981). The retinal location of global and local information in real world stimul will require empirical validation in order to settle the issue.

Perceptual Precedence and Bandwidth Models

It has been suggested that the results of the present study support a model in which perceptual precedence occurs through the sampling of certain critical sizes or spatial frequencies present in a visual stimulus. However, the finding that global forms or local elements are differentially favored in stimuli of different sizes tells little about the specific nature or width of the critical sampling band itself. In order to estimate the spatial frequencies present in the stimuli used in this study, and possibly suggest a range of spatial frequencies within the critical sampling bandwidth, the spatial frequencies of the global scenes and local objects used in the present study were determined at each of the three stimulus display sizes. The frequencies were computed by randomly placing lines in both the horizontal and vertical dimensions over each scene or object and counting the number of contours crossed by each line. A mean number of contours was then computed for each scene or object and this mean divided by the visual angle subtended by the scene or object at each size to yield the mean number of contour changes per degree of visual angle. Finally, the means were averaged across specific scenes (global forms) and across objects (local elements). These spatial frequencies, presented as numbers of contour changes per degree of visual angle, are shown in Table 4. Examination of the spatial frequencies shows that for the small displays, in which the global scenes were processed more rapidly, the mean number of changes per degree for the global scenes was 4.245. A very similar mean number of contour changes (spatial frequency) per degree was found for the local objects in the large displays and the local objects in the large displays were also found to produce short response latencies. Thus, approximately 4 contour changes per degree of visual angle is optimal for rapid perceptual processing, regardless of whether this occurs at a global or local level. In addition, the notion of a critical sampling bandwidth is strongly supported by the finding that trials with contour change values both higher (the local objects in the small size) and lower (the global scenes in the large size) result in longer response latencies than do trials with 4 contour changes per degree. The fact that the medium size displays also resulted in local precedence suggests that the 7.574 contour changes

Table 4

Mean Number of Contour Changes per Degree of Visual Angle

Size	Stimulus Level	
	Global	Local
Small	4.245	15.148
Medium	2.123	7.574
Large	1.082	3.787

per degree present in the medium size displays falls within the sampling bandwidth. Thus, the bandwidth can be estimated to range from between 2 to 3 contour changes up to 8 changes per degree of visual angle. In summary, the initially processed level of a stimulus seems to be that level whose spatial frequency falls within the sampling bandwidth of approximately 2.5 to 8 contour changes per degree of visual angle, irrespective of whether that level is either global or local.

Other evidence in support of a bandwidth model comes from the work of Harmon (1973), who found that in visual masking situations, the masks were only effective when the spatial frequency of the mask was within two octaves of the spatial frequency of the stimulus.

Clearly, much research is needed to verify the existence of a critical spatial frequency (or size) sampling bandwidth and to determine its nature and range. Before the bandwidth can be adequately explored, it will be necessary to develop an effective method for constructing pictorial stimuli of specific spatial frequencies in order to facilitate the experimental manipulation and study of the spatial frequency bandwidth model and its effect on perceptual precedence.

APPENDIX A

SUMMARY ANOVA TABLE OF LOG TRANSFORMED MEDIAN CORRECT-TRIAL LATENCIES

Table 5

Replication by Directed-Attention by Size by Consistency ANOVA Summary

Log Transform of Median Correct-Trial Latencies

Source	df	Mean Square	F
Replications (R)	1	0.005	0.062
Subjects within Replications (N/R)	38	0.074	---
Directed-Attention (A)	1	0.057	6.748*
R X A	1	0.001	0.134
A X N/R	38	0.008	---
Size (S)	2	0.151	97.265***
R X S	2	0.003	1.781
S X N/R	76	0.002	---
Consistency (C)	1	0.095	71.615***
R X C	1	0.002	1.314
C X N/R	38	0.001	---
A X S	2	0.029	27.268***
R X A X S	2	0.000	0.193
A X S X N/R	76	0.001	---
A X C	1	0.004	2.799
R X A X C	1	0.000	0.164
A X C X N/R	38	0.001	---

Table 5--Continued

Source	df	Mean Square	F
S X C	2	0.000	0.282
R X S X C	2	0.000	0.270
S X C X N/R	76	0.001	---
A X S X C	2	0.009	8.914***
R X A X S X C	2	0.000	0.209
A X S X C X N/R	76	0.001	---
TOTAL	479	0.009	

* $p < .05$
*** $p < .001$

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